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BASIC TECHNIQUES DIVISION

R.A.R.D.E. MEMORANDUM 8/67

Bore pitting in 81mm mortar barrels

J. Morris

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R.A.R.D.E.
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ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

R.A.R.D.E. MEMORANDUM 8/67

pp. 1

Bore pitting in 81mm mortar barrels

J. Morris (D2)

Summary

This report gives details of the examination of pitted barrels and concludes that the major cause of pitting is corrosion of the bores by decomposition products of the PVC. bomb obturating rings. Provisional trials with Polycarbonate obturating rings are described. It is considered that the use of Polycarbonate rings will eliminate the prime source of bore corrosion, namely chloride contamination, and also may well reduce the incidence of other forms of secondary corrosion.

Approved for issue:

S.W. Coppock, Principal Superintendent, 'D' Division

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1. INTRODUCTION

The phenomenon of bore pitting in 81 mm mortar barrels was first observed in barrel E/3099 and later in barrel L/66, both in service with the Proof and Experimental Establishment, Pendine, on Ammunition Proof and Trials firings. Incipient pitting of the bores of the barrels, in the form of a lightly etched dendritic pattern, commenced relatively early in the firing lives of these barrels and occurred initially at, and just forward of, the "rest" position of the bomb obturating ring - viz. - 33 inches to 28 inches from Muzzle End. The pitting became progressively more prolific with further firings, deepening in the initially affected regions and extending up the bore in a diminishing degree to the Muzzle ends of the barrels.

From periodic visual examinations with a boroscope and inspections of impressions taken on the bores it was considered that the pitting was not incipient scoring resulting from "gas-wash", but was a resultant of corrosion. Barrel cleaning and storage procedures at Pendine are excellent. It was noted that barrels at P. & E.E. Pendine having been cleaned for gauging and inspection, particularly after prolonged Ammunition Proof firings or sustained fire trials, exhibited discolouration of their bores some hours later, necessitating repeated cleanings and inspections.

2. EXAMINATION OF PITTED BARRELS

2.1 Examination procedure

One barrel was sectioned for metallurgical examination. Boroscope1 examinations were made in ten barrels and impressions were taken at intervals along the pitted regions of the bores of these barrels. The surfaces of the impressions were scanned with a Talysurf instrument to assess the depth of pitting. The bore residues of selected barrels were analysed by R.A.R.D.E/D3 Branch using conventional and X-ray fluorescence techniques. A further twelve barrels plus five 3-inch mortar barrels were visually examined only.

2.2 Barrels ex P. & E.E. Pendine

2.2.1 Barrel No. E/3099, in which bore pitting had rapidly progressed, was withdrawn from service after firing 2,305 rounds and was sectioned for metallurgical examination. Figure 1a., shows a general view of the bore pitting in this barrel and the relation of the commencement position of pitting to the "shot start" position of the bomb obturating ring is illustrated in Figure 1b. Photographs of unetched sections taken transversely and longitudinally in the region of heaviest pitting are given in Figures 2 and 3 respectively. The irregular form of the pits and the absence of thermally altered structure at their boundaries, as shown in Figure 4, confirmed the view that they were formed by corrosion not erosion. The maximum depth of pitting was found to be 0.0045 in.

From the location of the commencement of pitting in the bore it appeared that some degradation product or reaction product of the polyvinyl chloride (P.V.C - Trade name GEON) obturating ring produced a corrosive medium. Repeated applications in the laboratory of pieces of P.V.C obturating rings to prepared

surfaces of barrel material heated to 500°C failed to produce pitting possibly because of the absence of propellant gas temperatures and pressures, and of the opportunity for chlorine containing compounds to hydrolyse. However, the experiment did prove that when heated to temperatures of the order of 300°C and above the P.V.C. ring material gave off a considerable volume of acrid fumes whereas similar tests with a Polycarbonate (P.C. - Trade name MAKROLON) material showed this latter substance to be comparatively innocuous.

2.2.2 The pitting in Barrel No. L/66 developed more slowly than did that in E/3099 and after firing 11,328 rounds the maximum depth of bore pitting in L.66 was found to be 0.004 in. Overall bore wear in the barrel was slight and the barrel was considered to be very serviceable.

Comparative trials with P.V.C and Polycarbonate (P.C.) obturating were recommended as a result of these examinations.

2.3 Barrels ex Middle East Land Forces

2.3.1 After firings with P.V.C. obturated bombs six barrels in Service in the Middle East were provisionally condemmed for defects in their bores. On the return of these barrels to the U.K. visual examination proved the defects to be pitting similar in character and location to that in barrels E/3099 and L/66. Impressions were taken at intervals along the bores in the pitted areas; these impressions were then scanned with a Talysurf instrument to measure the depth of pitting. The results were as follows:-

Inches from	Barrel No. and Maximum depth of pitting - inches					
Muzzle End	L/20	L/112	L/114	L/125	L/127	L/209
2	0.0015	0.003	0.0015	0.001	0.0015	0.0015
12	0.002	0.003	0.003	0.002	0.002	0.003
22	0.003	0.0035	0.005	0.001	0.002	0.006
32	0.0065	0.006	0.0055	0.004*	0.006	0.0065

* Random tests in the region 30 to 32 inches. M.E. on barrel L/125 gave a maximum depth of pitting of 0.006 in.

Reproductions of some of the "Talysurf" traces from impressions taken on the bore of barrel L/209 are given in Figure 5. The barrels had a maximum bore wear of 0.004 in diametral in some of the pitted regions, however calculations by B.1 Branch indicated that, in all six barrels at the recommended service rate of fire, the reduction of wall thickness by pitting plus wear did not compromise the factor of safety of the barrels.

These barrels had each fired 1100 to 1300 rounds of 81 mm mortar ammunition and all except L/209 had also fired a considerable number of 3 inch bombs. The overall depth of pitting in these barrels was greater than that in E/3099 and L/66 which had fired considerably more 81 mm rounds.

Investigation by D3 Branch of the bore deposits of the barrels by conventional analysis techniques showed the presence of chlorides on the bores. Examination

of the contact side of a plastic impression of the internal surface of L/114 by X-ray fluorescence showed chlorine to be present, (contact side - 474 counts/sec., reverse side - 56 counts/sec.). Photographs were taken from outside the barrels with a studio camera aligned on the longitudinal axis from the Breech ends, Figure 6 showing barrel L/112 is representative of these.

2.3.2 Polycarbonate (P.C.) obturating rings and six new barrels were subsequently issued to a unit of M.E.L.F.; the P.C. rings were to replace the existing P.V.C. rings on bombs to be fired in these barrels. After firings in the field it was reported that these barrels, firing bombs obturated with P.C. rings, were showing signs of pitting in their bores. Unfortunately the barrels issued for this trial had fired P.V.C. obturated bombs at Proof and M.E.L.F. also reported that a small number of smoke and illuminating bombs - obturated with P.V.C. and nylon respectively - had of necessity been fired in the barrels.

Three of the six barrels were returned to the U.K., Their firing histories were - L/566 fired 702 rounds, L/580 fired 459 rounds and L/707 fired 608 rounds. Visual inspection showed L/566 and L/580 to be very clean and almost free from bore imperfections. L/707 had a very faint dendritic pattern on the bore near shot start with sporadic incipient pitting in this region. Impressions taken on the bores and measured in the same manner as those from the previous six (P.V.C.) barrels showed no unusual bore contours. Figure 7, shows a breech end view of the bore of L/707 for comparison with that of L/112 (Fig. 6).

Chemical examination by D3 Branch of washings of the above three barrels showed cellulose nitrate and traces of phosphates to be present in all three barrels; P.V.C. and Polycarbonate were not detected. No chlorine was detected by X-ray fluorescence examination of plastic impressions of the bore surfaces.

2.4 Barrels at the School of Infantry, Netheravon

Twelve 81mm mortar barrels were visually examined, their firing lives ranged from 2,411 to 3,579 rounds. In general they were heavily pitted in the bores in the same regions as the other pitted barrels. The order of the pitting was as severe and in some cases more severe than that found in the six M.E.L.F. barrels that had fired P.V.C. obturated bombs. Also examined were five 3 inch mortar barrels, four of which had fired some 81mm mortar bombs. These four barrels showed signs of pitting of the character observed in the 81mm barrels, whereas the fifth barrel which had fired 11,280 3 inch bombs had an almost unblemished bore surface.

3. R.A.R.D.E. FIRING TRIAL.

3.1 Equipment and ammunition

Consequent upon the signal from M.E.L.F. reporting pitting in the bores of barrels firing P.C. obturated bombs it was decided to mount a trial with new barrels, firing only one type of ammunition from each barrel. The trial consisted of three barrels proofed with unobturated, P.C. and P.V.C. obturated bombs respectively. Each barrel was then subjected to the following treatment:- a.m., Fire 60 rounds of the relevant ammunition at 15 r.p.m., stand in the "as fired"

condition until the following morning, clean and inspect, stand two hours, inspect further, then repeat the sequence. The firings took place on three successive days, a total of 180 rounds plus 4 proof rounds were fired from each barrel.

3.2 Trial results

(Firing or "shot start" position of obturating ring - 33in. from Muzzle End)

Barrel No.	L/539	L/521	L/530
Ammunition fired	Unobturated	Obturated P.C.	Obturated P.V.C.
After 1st firing Max. Barrel Temp. Bore Condition	120°C Black deposit with clean patches from M.E. to 33 in. M.E.	N.R. Black deposits M.E. to 13 in. M.E. and 16 to 33 in. M.E. remainder clean	190°C Black deposit from M.E. to 33 in. M.E. Remainder clean
After normal Service clean with Brush	Clean except for slight black spots at 33 in. M.E.	Clean except for black patch over half circumference at M.E. to 10" M.E.	Streaky black deposit from 16 to 33 in. M.E. otherwise clean
After cleaning with wire wool	Clean overall	Clean overall	Clean except for circumferential black mark at 33 in. M.E.
After 2nd Firing Max. Barrel Temp. Bore Condition	200°C Black deposit at 24 to 33 in M.E. Black streaks from M.E. to 24 in. M.E.	140°C Black deposit M.E. to 3 in. M.E. Patches at 14, 19 and 28 in. M.E.	210°C Heavy black deposit from M.E. to 33in. M.E.
After normal service clean	Black deposit from 26 to 33 in. M.E. Intermittent patches from 5 to 26 in. M.E.	Light staining from Breech end to 6 in. M.E. Some deposit M.E. to 3 in. M.E.	Light deposit from 10 to 33 in. M.E.
After cleaning with wire wool	Clean with slight staining at 32 to 33 in. M.E.	Clean overall	Patches of black deposit at 27 to 33 in. M.E. and 19 to 22 in. M.E. Black ring at 33 in. M.E.

Barrel No.	L/539	L/521	L530
Ammunition fired	Unobturated	Obturated P.C.	Obturated P.V.C.
After 3rd firing Max. Barrel Temp. Bore Condition	300°C Black deposits from B.E. to 33 in. M.E. and 15 to 18 in. M.E. otherwise fairly clean	180°C Black streaks from M.E. to 33 in. M.E. Black deposits overall from B.E. to 33 in. M.E. and 15 to 18 in. M.E.	180°C Black overall Heavy deposits at 33 in. M.E. and 11 to 14 in. M.E.
After Normal Service clean	Mainly clean Black deposit in band 33 to 34 in. M.E. and patches at 25 to 33 in. M.E.	Black streaks from M.E. to 34 in. M.E. with black ring at 33 in. M.E. and dark band at 15 to 18 in. M.E.	Black streaks throughout bore Possible etching pattern at 26 to 33 in. M.E. Black band at 12 to 14 in. M.E.
After cleaning with wire wool	Almost clean except for black band over half of circumference at 33 in. M.E.	Very clean Small black patches at 33 in. M.E.	Black streaks from 17 to 33 in. M.E. Black circular deposit at 33 in. M.E.

In the two hourly periods between cleaning and the next firings it was noted that the bore surface of L/530 (P.V.C. rings) blackened slightly; no alteration was observed in the bore conditions of the other two barrels. At the completion of the trial there was no definite evidence of pitting in any of the barrels.

3.3 Examination of the barrels from R.A.R.D.E Trial

3.3.1 The barrels were left in the "as cleaned" condition on completion of the trial. On receipt in R.A.R.D.E/D2, twelve days after the last cleaning, it was observed that there had been a very slight increase in the area of the black deposits in the bores of the barrels that fired unobturated and P.C. obturated bombs. (L/539 and L/521) In contrast there had been considerable build up of deposits on the bore of the barrel which fired P.V.C. obturated bombs. There were heavy black deposits throughout the full area of shot travel with streaks of rust, in appearance the barrel bore was dirtier than it was in the "as fired" condition. Figures 8, 9 and 10 show the appearance of the bores on receipt in R.A.R.D.E. Barrel L/530 (fired P.V.C.) was given a light brush-through before photographing to aid definition - Figure 10.

3.2.2 Subsequently the barrels were passed to D.3 Branch for chemical examination. After samples had been taken from the bores the barrels were cleaned. L/521 (P.C.) showed no etching or pitting effects, L/539 (unobturated) showed very slight traces of etching, in areas where some rusting had occurred, and

L/530 showed definite etching and incipient pitting. Analysis of rust from L/530 showed chloride and nitrate to be present. There was no evidence of nitrocellulose, P.V.C. or other identifiable organic material in the other two barrels.

4. DISCUSSION

Two 81 mm mortar barrels, Nos. E.3099 and L.66, fired at P. & E.E. Pendine developed pitting in their bores, commencing at the firing position of the obturating ring - 33 in. M.E. - and extending with diminishing depth forward to the muzzle end. After firing 2,305 rounds barrel E.3099, in which the pitting had progressed more rapidly, was sectioned for examination. The bore pits were found to be a function of corrosion not of erosion and of maximum depth 0.0045 in. Barrel L.66 fired 11,328 rounds before the bore condition was similar to that of E.3099.

Six barrels fired in the field by M.E.L.F. were similarly pitted after firing an average of 1200 81 mm bombs each; the maximum depth of pitting in these barrels was 0.006 in. in all cases. The existence of chloride residues, derived from the P.V.C. obturating ring, on these bores was established by D3 Branch and it was considered that corrosive action would continue after cleaning and during storage.

Twelve barrels in service with the School of Infantry, Netheravon, also fired P.V.C. obturated bombs. Their firing lives ranges from 2,411 to 3,579 rounds and the pitting in the bores of these barrels is possibly more severe than in the M.E.L.F. barrels. Four 3 inch mortar barrels at this station had also fired 81 mm bombs and they exhibited some pitting in their bores.

A R.A.R.D.E trial was carried out with three new barrels which fired unobturated, P.V.C. obturated, and P.C. obturated ammunition, respectively. This trial demonstrated the difficulty in keeping clean a barrel fired with P.V.C. obturated bombs. The barrels were thoroughly cleaned on completion of firing, no bore pitting was evident in any of the barrels. However, twelve days after cleaning, the barrels which fired unobturated and P.C. obturated ammunition were in much the same condition as after cleaning, whereas the barrel which fired P.V.C. obturated bombs had suffered sufficient corrosive action by remanent chlorides to present an "as fired" appearance in the bore. After examination by D.3 Branch and final cleaning the bore of this latter barrel showed evidence of the onset of pitting. Chemical analysis showed the bore of this barrel to be contaminated with chloride and nitrate, little or no contamination was found in the bores of the other two barrels. It was considered that the continuation of this trial to give definite and extensive bore pitting was not necessary.

Pitting has been observed in 81 mm mortar barrels of Cr-Mo-V steel, in 3 inch mortar barrels of Ni-Cr-Mo steel and in an 81 mm barrel of RARDE steel - Si-Mo-Cu-V-Co. Steel composition evidently plays little part. Differences in extent and severity of the bore pitting in mortar barrels firing P.V.C. obturated bombs, when considered relative to their firing histories, are due to local

conditions, cleaning facilities and frequency of cleaning and possible variations in the lots of P.V.C. rings.

Obturating rings made of a Polycarbonate material have been recommended as a replacement for the P.V.C. rings, to obviate chloride contamination of bores. Barrels fired by M.E.L.F. with P.C. obturated bombs were reported to be pitted in their bores. This report proved to be exaggerated, no measurable pitting was found in the barrels, and it is considered that the bores are in excellent condition. Such bore blemishes as are visible are possibly due to the action of some chlorides remanent on the bores from the P.V.C. obturated Proof rounds and other small numbers of non-polycarbonate obturated bombs fired during service.

The results confirm that corrosion induced by decomposition products of P.V.C. is the major cause of pitting in the bores of 81 mm mortar barrels. There are other products arising from decomposition of the propellant and the secondary containers, particularly nitrates, which may also foster bore corrosion, however their effect is of a lower order than that of chlorides. The cleaning effect of P.C. rings on passage up the bore appears to prevent build up of such second order residues.

The Polycarbonate obturating ring is ballistically the same as the P.V.C. ring, it permits a slightly faster free fall of the bomb in the barrel and it is also much cheaper than the P.V.C. ring. The replacement of P.V.C. obturating rings by Polycarbonate rings is proceeding rapidly and, though a large number of barrels have been proofed with P.V.C. obturated bombs and will have some bore contamination, it is considered that the use of P.C. obturating rings will considerably increase the firing lives of these barrels. All current Proof firing is done with P.C. obturated bombs. D.3 Branch recommend that, particularly where PVC obturated ammunition has been used, barrels after firing should be washed out with hot water containing a detergent, rinsed and dried, before oiling with oil PX-4.

It is conceivable that if bore pitting in barrels is allowed to progress, a stage may be reached where the escape of propellant gas along strings of pits could lead to relatively rapid erosion. In order to assess the permissible depth of bore pitting in barrels currently in service it is proposed to subject one of the M.E.L.F. pitted barrels, and also a barrel which was machined in the bore to the condemming limit for wear, to repeated firings, interspersed with accelerated corrosion conditions until failure or excessive bulging occurs.

A demonstration of the effectiveness of Polycarbonate obturating rings in inhibiting bore corrosion under Service conditions is being arranged. It will be conducted in the Middle East by a R.A.R.D.E representative in co-operation with a unit in the field.

5. CONCLUSIONS

5.1 Bore pitting recently experienced in 81 mm mortar barrels is the result of corrosion induced by chlorine-containing degradation products from polyvinyl chloride obturating rings.

5.2 Such corrosion takes place in spite of, and largely subsequent to, normal cleaning after firing.

5.3 Polycarbonate obturating rings did not give rise to objectionable pitting troubles. Replacement of PVC by polycarbonate obturating rings is proceeding rapidly.

5.4 Pitting of the extent so far encountered in no way compromises the safety of the barrel which is in fact able to withstand much deeper and sharper notches.

5.5 A permissible depth of pitting for Service barrels is being determined by a current trial and recommendations will be issued.

6. RECOMMENDATION

It is recommended that, particularly where P.V.C. obturated ammunition has been used, barrels after firing should be cleaned by scrubbing with hot water containing a detergent. They should then be rinsed and dried before oiling with PX-4.

7. ACKNOWLEDGEMENTS

The author wishes to express the thanks of his section to the Corrosion section of D3 Branch for reports and recommendations resulting from examinations of bore deposits, to B1 Branch for arranging trials and the movements of barrels, to E/E Metrology section for the preparation and measurements of bore impressions, and to D.I.Arm Staff of P. & E.E. Pendine for observations during routine and Trial firings.

FIG. 1.

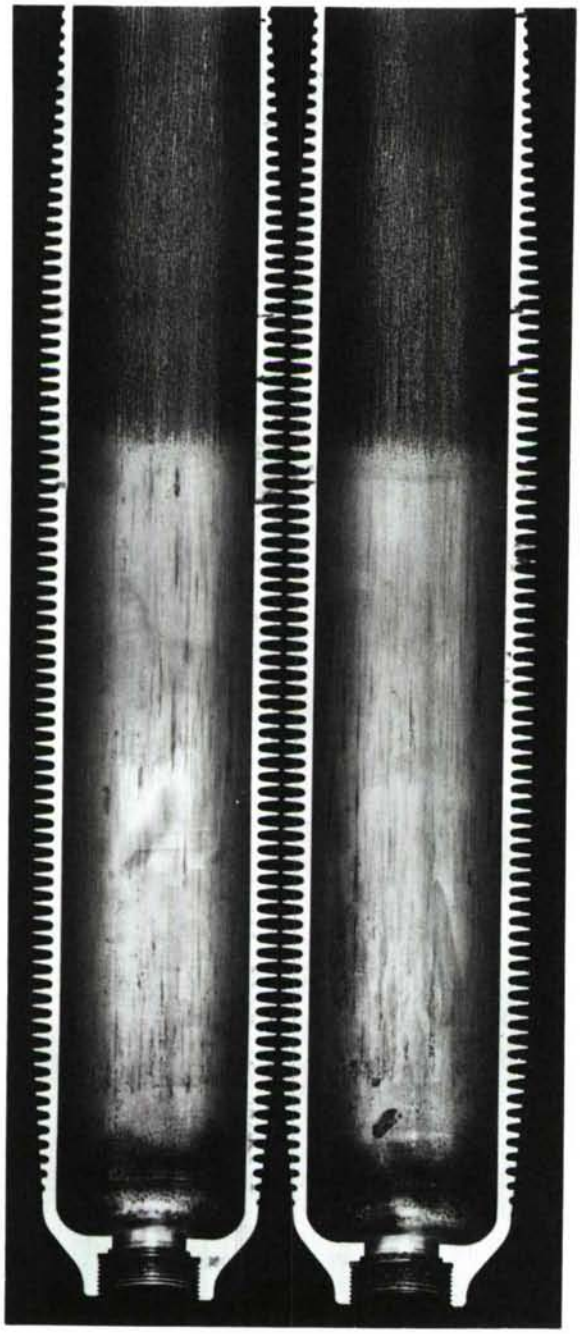

FIG. 1a. Barrel E/3099.
showing bore condition from
Breech end to 25 in. M.E. x 1/3

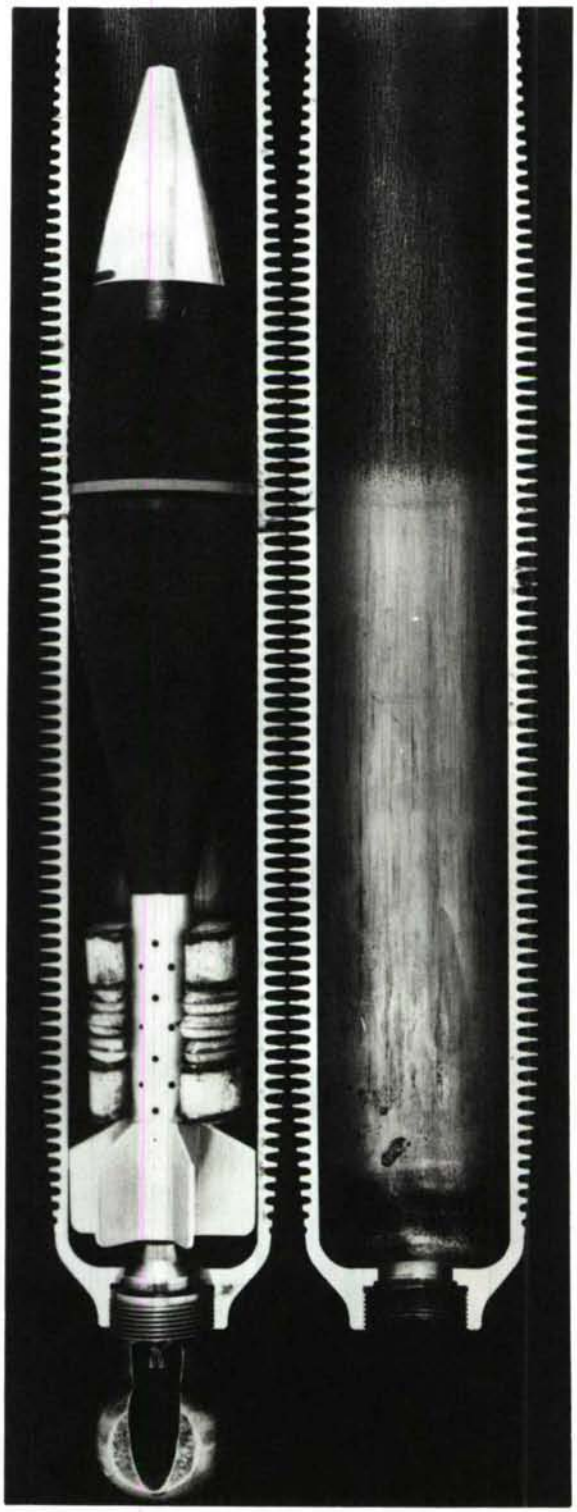

FIG. 1b. – as 1a – with bomb
and base plug in firing
position.

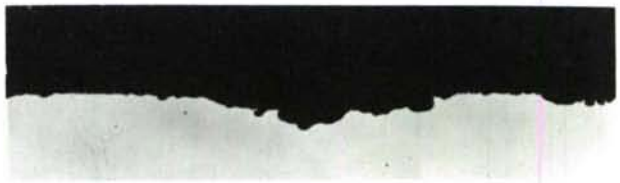

FIG. 2. Barrel E/3099. Unetched transverse section at 30 in. M.E. ×25

FIG. 3. As fig. 2, longitudinal section. ×25

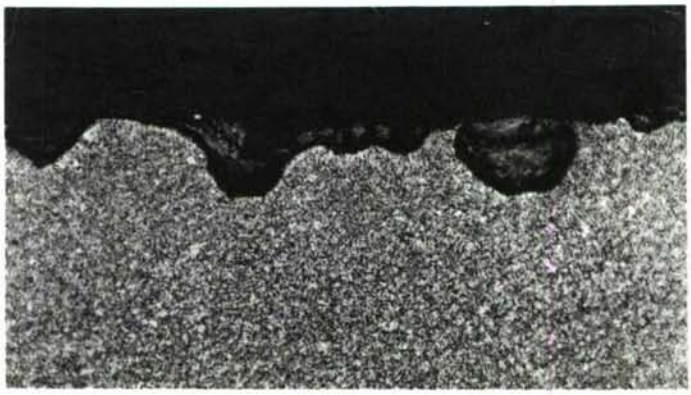

FIG. 4. Etched portion of section in fig. 2 ×100

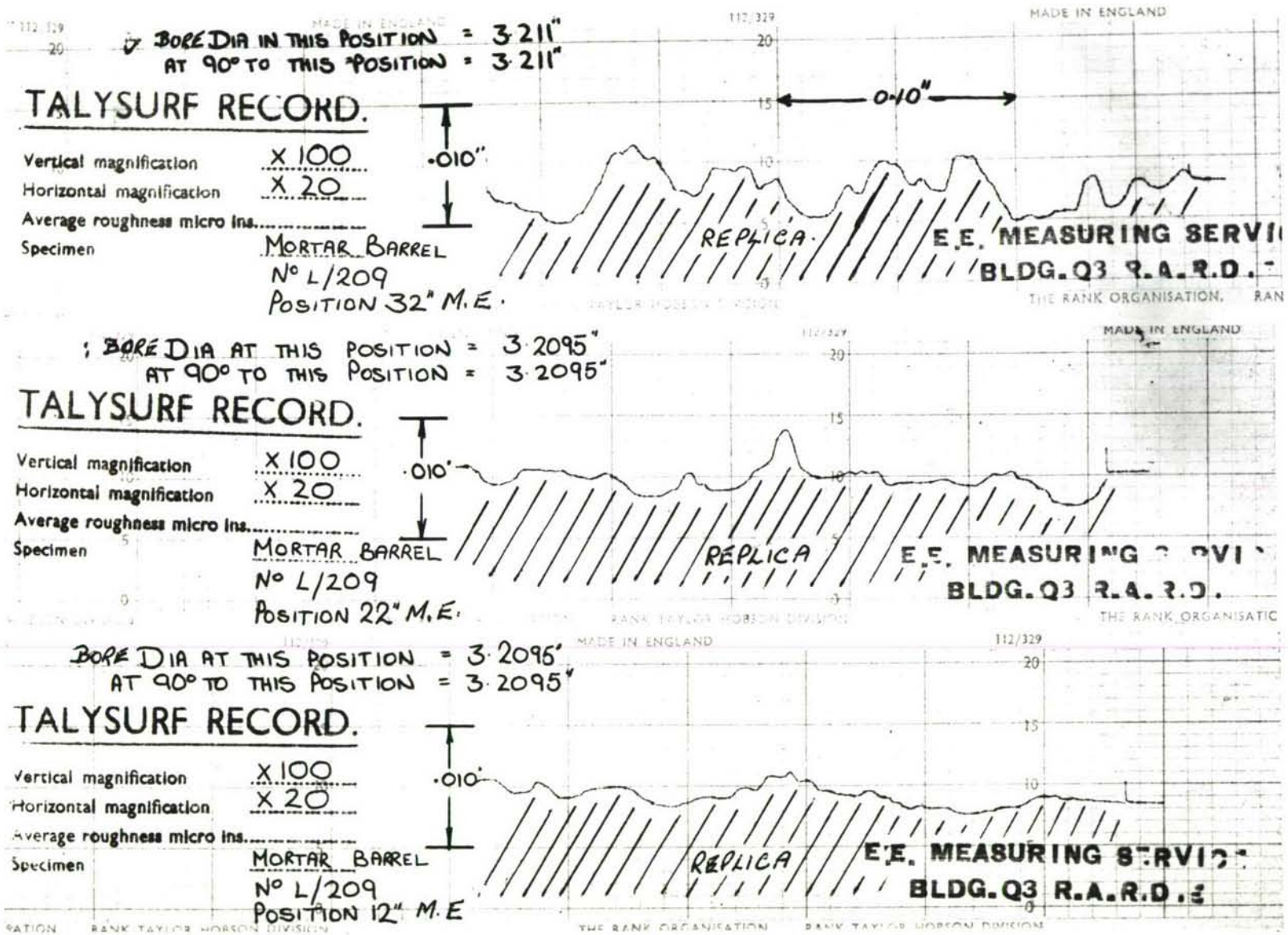

FIG.5. 'Talysurf' traces taken on plastic impressions of bore surface of Barrel L/209.

FIG.5.

FIG.6. Barrel L/112. Ex M.E.L.F. Fired 1228 bombs obturated P.V.C. rings. Breech end view.

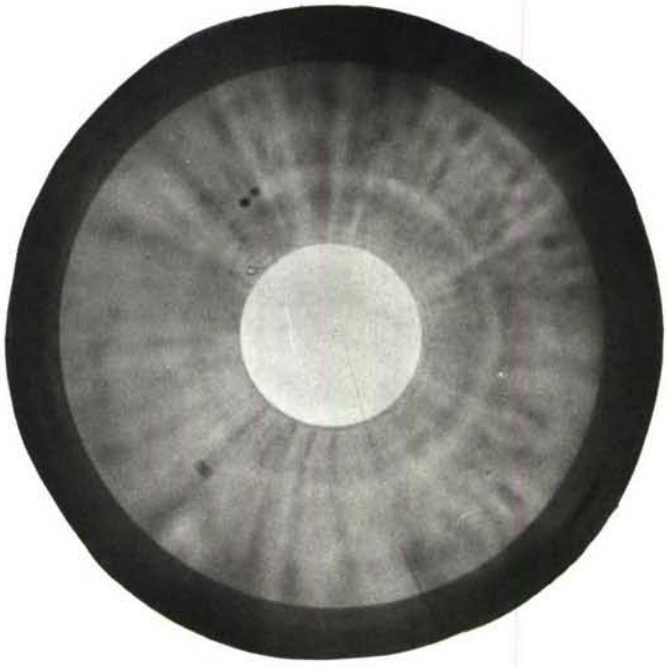

FIG. 7. Barrel L/707. Ex M.E.L.F. Fired 608 bombs obturated Polycarbonate rings. Breech end view.

FIG.8. Barrel L/521.
R.A.R.D.E trial, fired 184 bombs obturated with Polycarbonate rings.
Breech end view.

FIG.9. Barrel L/539.
As fig.8, bombs unobturated.

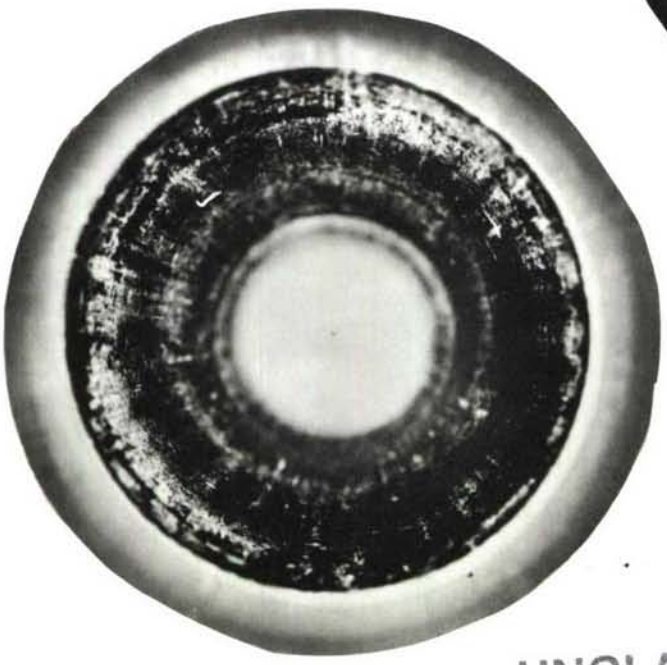

FIG.10. Barrel L/530.
As fig.8, bombs obturated P.V.C. Barrel lightly cleaned before photograph was taken.

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623.421.4 '81mm':
623,423,3:
620.191.36:
623.457.7

Bore pitting in 81mm mortar barrels
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8 pp. 10 figs.

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